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Plastics piping systems — Multilayer pipes — Determination of long-term strength

Systèmes de canalisations en matières plastiques — Tubes multicouches — Détermination de la résistance à long terme

Reference number
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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 17456 was prepared by Technical Committee ISO/TC 138, *Plastics pipes, fittings and valves for the transport of fluids*, Subcommittee SC 5, *General properties of pipes, fittings and valves of plastic materials and their accessories — Test methods and basic specifications*.

Introduction

This is one of three International Standards developed by ISO/TC 138/SC 5, following the creation of the Subcommittee's Working Group WG 16 at Kyoto, Japan, in 1998, in response to worldwide demand for specifications, requirements and test methods for multilayer plastics pipes. The others are ISO 17454 [1] and ISO 17455 [2].

Only multilayer pipes are dealt with in this International Standard and for its purposes cross-linked polyethylene (PEX) as well as adhesives are to be considered as a thermoplastics material.

The long-term pressure strength of a multilayer pipe can be measured experimentally using pressure test data acquired by testing multilayer pipes to failure.

Alternatively, the pressure strength of the pipe can be theoretically determined using an equation (see Annex A) that calculates the pressure resistance of each individual pipe layer from the layer dimensions and the long-term hydrostatic strength of the layer material: the long-term pressure strength of the multilayer pipe is then the sum of the calculated pressure strengths of the individual pipe layers.

Consequently, two procedures for the determination of the long-term pressure strength of multilayer pipes are given by this International Standard: Procedure I, a calculation method applicable for type P pipes only, and Procedure II, a pressure test method applicable for both types P and M pipes. At the time of publication of this International Standard, no calculation method existed for predicting the long-term strength of a multilayer M pipe, taking into account all possible constructions.

Although 100 % adhesion between individual layers is assumed, Procedure I does not take this into account. Confirmation pressure tests are necessary for assessing possible interaction effects between layers and for validating the use of the method (see Annex A).

Plastics piping systems — Multilayer pipes — Determination of long-term strength

1 Scope

This International Standard specifies two alternative methods for determining the long-term hydrostatic strength of multilayer pipes: a calculation method applicable to multilayer P pipes (all polymer layers) and a test method applicable to both multilayer P and multilayer M pipes (polymer and metal layers).

This International Standard is not applicable to pipes consisting of one polymeric stress-designed layer or having an outside polymeric layer that is not stress-designed. Those types of multilayer pipe are covered by the International Standards referenced in Clause 2.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 1167-1, *Thermoplastics pipes, fittings and assemblies for the conveyance of fluids — Determination of the resistance to internal pressure — Part 1: General method*

ISO 1167-2, *Thermoplastics pipes, fittings and assemblies for the conveyance of fluids — Determination of the resistance to internal pressure — Part 2: Preparation of pipe test pieces*

ISO 9080, *Plastics piping and ducting systems — Determination of the long-term hydrostatic strength of thermoplastics materials in pipe form by extrapolation*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

3.1
multilayer pipe
pipe comprising layers of different materials

3.2
multilayer M pipe
pipe comprised of stress-designed polymeric layers and one or more stress-designed metallic layers

NOTE The wall thickness of the pipe consists of at least 60 % of polymeric materials (e.g. PEX/Al/PEX or PE-RT/Al/PEX).

3.3
multilayer P pipe
pipe comprised of more than one stress-designed polymeric layers (e.g. PVC-C/PEX)

3.4
similar construction type
⟨multilayer P pipes⟩ construction type that is the same for more than one pipe diameter under conditions where

— the same process technology is used,

— materials having the same characteristics are used for each stress bearing layer: i.e. material type and specifications,

— the layers are assembled in the same sequence for different diameters, and

— for all diameters, the standard dimension ratio (SDR) of each stress-designed layer is equal to the design value ± 10 %.

NOTE See Clause 5.

3.5
similar construction type
⟨multilayer M pipes⟩ construction type that is the same for more than one pipe diameter under conditions where

— the same process technology is used (e.g. welding process for the aluminium layers, type of welding, etc.),

— materials having the same characteristics are used for each stress bearing layer, i.e. material type and specifications,

— the layers are assembled in the same sequence for different diameters, and

— for all diameters, the metal-layer standard dimension ratio (SDR_m) is, ± 10 %, the same.

NOTE If, for a certain diameter range, the same metal layer thickness is used, the SDR_m value of the metal layer of all smaller diameters of this diameter range can be adapted up to the SDR_m of the metal layer for the largest diameter of the diameter range (e.g. a diameter range from 12 mm up to 20 mm with a 0,2 mm metal layer).

3.6
metal layer standard dimension ratio
SDR_m
nominal outside diameter (DN or OD) divided by the nominal wall thickness of the metal layers, $e_{n,m}$

3.7
lower confidence limit of the predicted hydrostatic pressure
p_{LPL}
quantity with the dimension of pressure, which represents the 97,5 % (one sided) lower confidence limit of the predicted hydrostatic pressure at a temperature, T, and a time, t

3.8
lower confidence limit of the predicted hydrostatic strength
σ_{LPL}
quantity in megapascals (MPa), with the dimensions of stress, which represents the 97,5 % lower confidence limit of the predicted hydrostatic strength at a temperature, T, and a time, t

3.9
procedure I
calculation method for determination of the long-term hydrostatic pressure strength of multilayer P pipes

3.10
procedure II
test method for determination of the long-term hydrostatic pressure strength of both multilayer M pipes and multilayer P pipes

3.11
long-term hydrostatic pressure
p_{LTHS}
quantity with the dimension of pressure, which represents the predicted mean pressure at a temperature, T, and time, t (50 % confidence limit)

3.12
long-term hydrostatic strength
σ_{LTHS}
quantity with the dimensions of stress, expressed in megapascals (MPa), which represents the predicted mean strength at a temperature, T, and time, t

3.13
referring product standard
International Standard or Draft International Standard prepared by ISO/TC 138/SC 2, PVC pipes, and applicable to pipes other than multilayer pipes, to which this International Standard refers for clauses related to the materials

4 Principle

The long-term pressure strength of the multilayer pipe construction is determined either

a) by calculation (for multilayer P pipes only) using the equation given in Annex A, which incorporates the dimensions of each layer and the LTHS of each layer material using ISO 9080 or “reference lines” as directed by the referring product standard, or

b) by analyses of the results of a series of pressure tests conducted on the multilayer pipe (for both multilayer M and multilayer P pipes).

In the case of a), it is necessary to validate the use of the Annex A equation for each design of multilayer pipe by a confirmation test.

NOTE It is assumed that the following test parameters of stress bearing layers have been set by the referring product standard or the manufacturer’s instructions:

— for M pipes, the dimension groups, if applicable (see 6.2.3.1);

— wall stress and/or test pressure.

5 Test pieces

Test pieces shall be prepared in accordance with ISO 1167-2.

P-pipes with the same overall wall thickness within a diameter group are considered to be of a similar construction type and only the largest diameter within that diameter group shall be tested.

6 Determination of long-term strength [1)]

6.1 Procedure I — Calculation method

6.1.1 General

This procedure is only applicable to multilayer P pipes. The calculation method utilises experimental data derived from the conduct of stress rupture tests on the material of each stress-designed layer according to ISO 1167-1.

6.1.2 Calculation of long-term pressure strength

The calculation of the long-term pressure strength of the multilayer P pipe shall be made using the equation given in Annex A.

The calculation shall be made using data obtained according to 6.1.1 and analysed to determine the $\sigma_{\mathrm{LPL}(T,t,0,975)}$ of each layer material using the rules given in ISO 9080.

Existing reference lines from the referring product standard shall be used to determine the long-term strength of each stress-designed layer.

If no reference lines exist for the material, the data shall be generated in accordance with ISO 9080.

6.1.3 Validation

The Annex A equation does not take into account possible interaction effects between layers. Validation of the use of the equation is necessary for each design of multilayer pipe.

Using the equation in Annex A and the long-term strength characteristic for each stress-designed layer material, generated either by ISO 9080 analysis or reference lines as appropriate, calculate the validation test pressures for the following conditions:

— $T = 80$ °C at $t = 3\,000$ h, or

— $T = 95$ °C at $t = 1\,000$ h.

Tests at lower elevated temperatures (e.g. 60 °C, 3 000 h) may be necessary in order to avoid material degradation and align with product standard requirements.

The multilayer pipe shall withstand the calculated validation pressure for the test periods specified above.

For a given pipe construction validation, test failure shall lead to testing in accordance with Procedure II in order to determine the long-term pressure strength.

The mean of the tolerance range of each stress-designed layer, as specified by the pipe producer, shall be used for the calculation.

6.1.4 Control point tests

The reference values or the $\sigma_{\mathrm{LPL}(T,t,0,975)}$ derived from the ISO 9080 analysis shall be used to calculate the test pressure.

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1) The flow diagram given in Annex B describes the procedure to be followed for every multilayer pipe design.

6.2 Procedure II — Pressure test

6.2.1 General

The pressure test method measures the long-term pressure strength of multilayer pipe directly. The procedure according to ISO 1167-1, using test pieces prepared in accordance with ISO 1167-2, shall be followed.

6.2.2 Test procedure

Carry out a series of pressure tests to failure on one pipe diameter of every dimension group. The spread of failure data shall conform to the requirements of ISO 9080. For multilayer M pipes the diameter with the highest SDR of the metal layer shall be used.

Determination of the long-term pressure strength at the required time and temperature shall be obtained by analysis in accordance with ISO 9080.

6.2.3 Complete testing

6.2.3.1 Unless otherwise specified by the referring product standard, the dimension groups according to 6.2.3.2 shall apply.

6.2.3.2 Evaluate at least one diameter of every *similar construction type* in accordance with ISO 9080 for each group of dimensions as follows:

— dimension group 1, all nominal dimensions less than or equal to 26 mm;

— dimension group 2, all nominal dimensions greater than 26 mm and less than or equal to 63 mm;

— dimension group 3, all nominal dimensions greater than 63 mm.

6.2.3.3 Using ISO 9080 and the information contained in the test report obtained following 6.2.2, determine the long-term hydrostatic strength.

Compare the results with the requirements specified in the referring product standard.

6.2.4 Confirmation testing

6.2.4.1 Unless otherwise specified by the referring product standard, confirmation testing shall be carried out in order to determine the 5 year value of p_{LTHS} of the pipe dimensions not fully tested (according to 6.2.3) . This value shall be at least 90 % of the 5 year value of the pipe dimension fully tested according to 6.2.3.

Tests are required to confirm the applicability to other pipe sizes of the long-term pressure strength determined according to 6.1.2 or 6.2.2.

6.2.4.2 Unless otherwise specified by the referring product standard, the test temperature shall be 80 °C.

At least 18 failures shall appear, equally spread from 10 h to 10 000 h.

Per time interval, at least 6 fractures shall appear. At least 3 fractures shall appear on or above 4 000 h.

NOTE According to ISO 9080, pipes without failure can be counted as failure points if conditions are fulfilled.

6.2.4.3 The extrapolated 5 year results for each diameter, expressed by the $p_{\mathrm{LTHS,\ 5\text{-}year}}$ value and $T_{\mathrm{5\text{-}year}}$, shall be greater than 90 % of the $p_{\mathrm{LTHS,\ 5\text{-}year}}$ value of the diameter tested according 6.2.3.

6.2.5 Control point tests

Control points at the required time and at a temperature according to the referring product standard shall be calculated using the 95 % value of the p_{LPL} of the fully tested diameter, for each diameter for 22 h, 165 h and 1 000 h (or other required testing time).

7 Test report

The report shall include the following information:

a) reference to this International Standard, the referring product standard and the manufacturer's instructions;

b) complete identification of the multilayer pipe component from which the test piece was taken, including manufacturer, material type, code number, size, source and significant history, if any;

c) dimensions of the pipes used for the testing;

d) number of test pieces;

e) table of observations, including for each observation, the test temperature (in degrees Celsius), pressure level (in bar), stress level (in megapascals) in the case of multilayer type P pipes, time to failure (in hours), data of the test, and any other relevant observations;

f) graph presenting observed failure points and linear regression lines;

g) any factors that may have affected the results, such as incidents or operation details not mentioned in this International Standard;

h) date of test.

Annex A
(normative)

Validation of the pressure strength (Procedure I)

This annex gives the equation for the calculation of the long-term pressure strength, the pressure strength for confirmation or the pressure strength for the control points.

For the confirmation test, σ_n of each stress bearing material shall be for the same t and T.

The hydraulic pressure of the P pipe, expressed in bar, shall be calculated using Equation (A.1):

$$p_{T,t} = 20\sum_{1}^{n}\frac{e_n\sigma_n}{d_n - e_n} \qquad \text{(A.1)}$$

where

e_n is the wall thickness of the designed stress bearing layer, in millimetres;

n is the number of designed stress bearing layers;

d_n is the outside diameter of stress bearing material, in millimetres;

σ_n is the hoop stress, expressed in megapascals[2)], determined for the material in accordance with the relevant product standard or system standard for temperature T, in degrees Celsius, at a time t, in hours;

$p_{T,t}$ is the calculated pressure at temperature T and for time t for the multilayer pipe, expressed in bar[2)].

When the relevant product or system standard gives no time and temperature for the testing, the following parameters are recommended:

— $T = 80$ °C with $t = 3\,000$ h, or

— $T = 95$ °C with $t = 1\,000$ h.

2) 1 bar = 0,1 MPa = 10^5 Pa; 1 MPa = 1 N/mm^2

Annex B
(informative)

Flow chart of long-term strength determination

Figure B.1 shows a flow chart of the procedures for determining the long-term strength of a multilayer pipe design according to this International Standard.

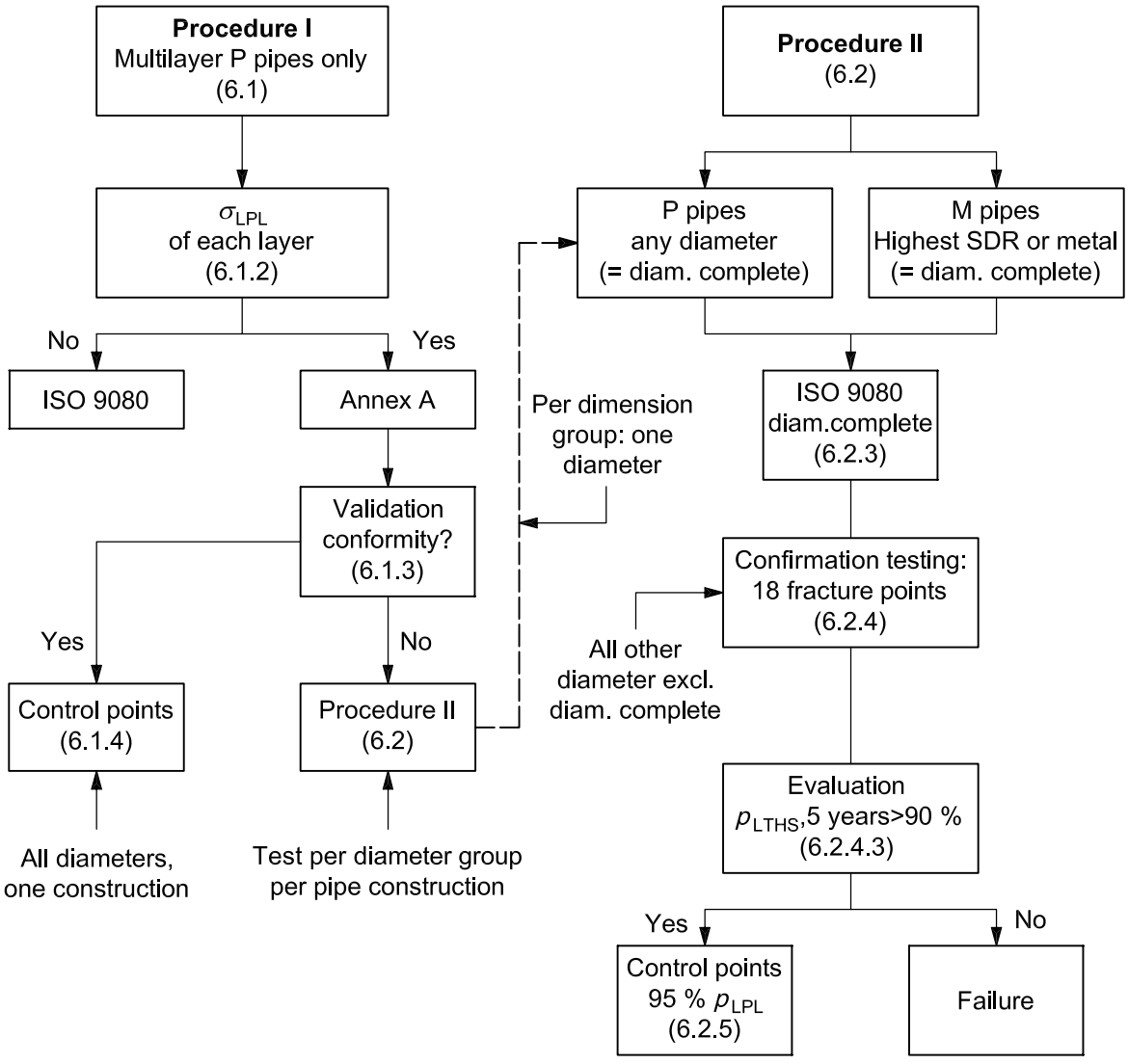

Figure B.1

Bibliography

[1] ISO 17454:2006, *Plastics piping systems — Multilayer pipes — Test method for the adhesion of the different layers using a pulling rig*

[2] ISO 17455:2005, *Plastics piping systems — Multilayer pipes — Determination of the oxygen permeability of the barrier pipe*

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